LAUSSENLABS

SickKids

Improving quality of care in critically ill children by real-time detection of bedside interventions using physiological waveforms and deep learning

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Introduction

- In the Critical Care Unit (CCU), vascular catheters are a vital tool to access the bloodstream for sampling, pressure measurements, and drug administration.
- Overutilization of catheters is associated with adverse outcomes such as bloodstream infections [1]. Awareness of catheter utilization is required to reduce adverse outcomes and improve quality of care [2].
- Currently catheter utilization is manually documented and is subject to error, omission, and bias.
- We identified a characteristic artefact in blood pressure waveform data that occurs during each catheter access (Figure 1).
- We developed, tested, and implemented a novel deep learning tool to accurately detect these artefacts in real-time as a means of automating detection of catheter access.

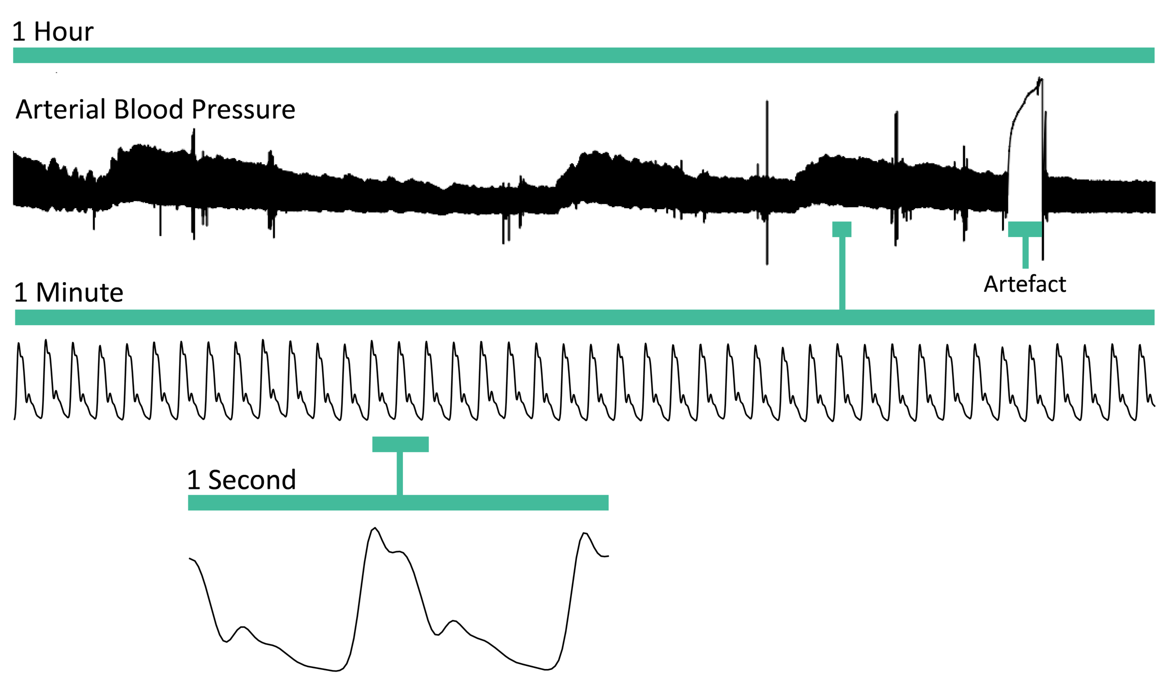

Figure 1. Arterial blood pressure waveform data showing catheter access artefact.

Objective

Develop and deploy a machine-learning tool capable of accurately detecting catheter access events in real-time

1. Bell, T. & O'Grady, N. P. Prevention of Central Line–Associated Bloodstream Infections. Infectious Disease Clinics of North America vol. 31 551–559 (2017).
2. McDonald, E. G. & Lee, T. C. Reduction of central venous catheter use in medical inpatients through regular physician audits using an online tool. JAMA Internal Medicine vol. 175 1232–1234 (2015).

Methodology

- **Convolutional Neural Network** binary classifier
- **Labelled training dataset of ~1800 arterial line artefacts** from direct, timed observation and manual labeling of line access events by clinical observers
- One-minute intervals split into training/testing/validation sets (60%/20%/20%)
  - Training data: n=1358 with artefact, n=9896 without artefact
- One calendar **year of continuous waveform data** (n=548 artefacts) was held out to **simulate prospective deployment** by retaining the noise and class imbalance found in real-time data

Real-time Deployment

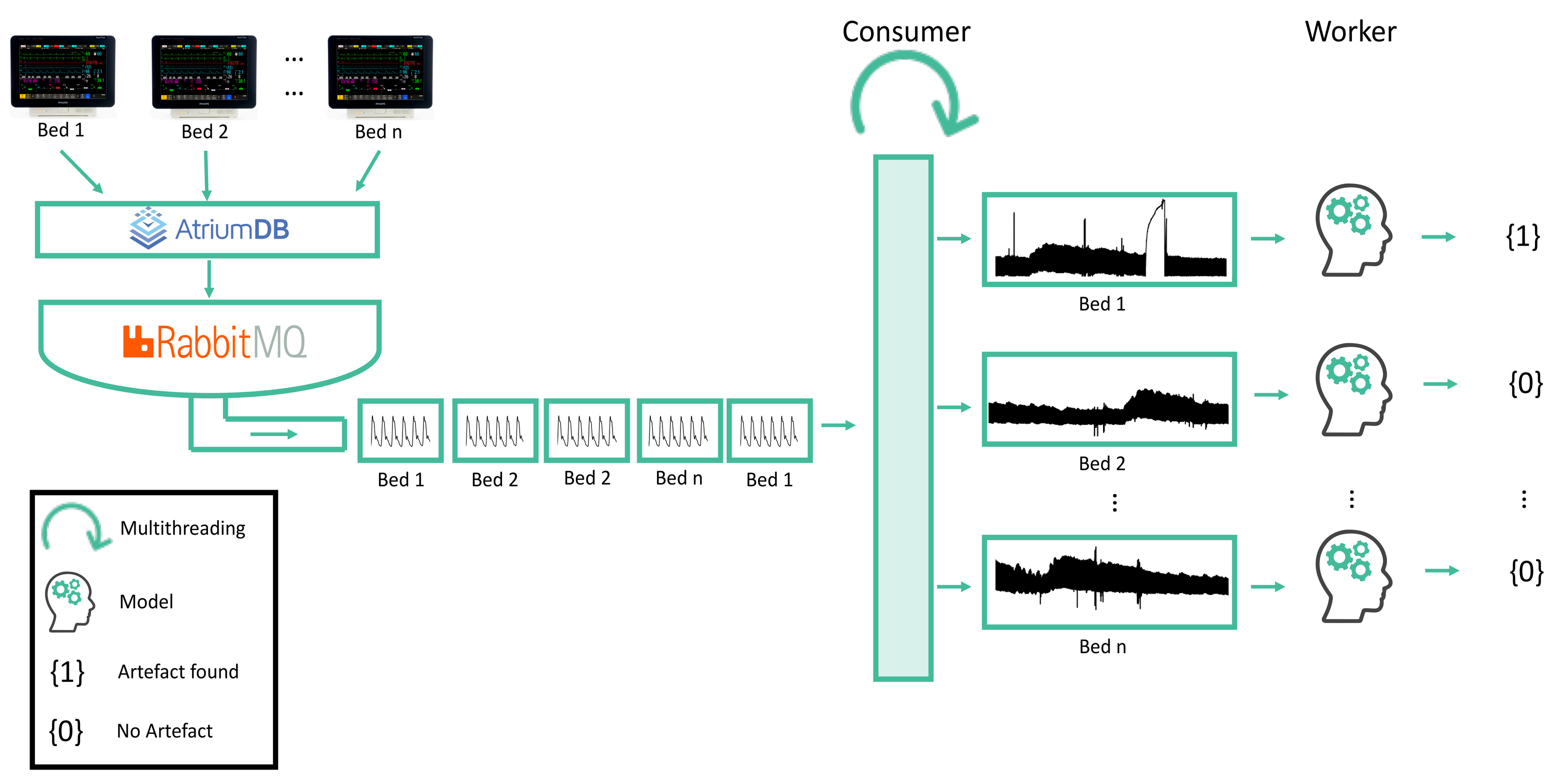

Figure 2. Real-time streaming pipeline of waveform data from CCU bedspaces to model inference.

- **Streaming data from CCU bedspaces are stored in our proprietary time-series database, AtriumDB.**
- **Messaging queue system:** RabbitMQ, ingests waveform intervals from AtriumDB and passes them to our inference script.
- **'Consumer' script:** aggregates, preprocesses the waveform, and passes them to a **'Worker' script:** conducts model inference.
- Metadata about the waveform (bedspace and timestamps) and the Sigmoid scores from the **model predictions are stored in a MariaDB database**.

Results

- A simple ML model can detect arterial line artefacts corresponding to bedtime interventions with high accuracy, sensitivity, and specificity
- This **model is accurate and robust to the class imbalance and noise of real-world data**, when evaluated on one continuous year of waveform data
- Preparation is underway for a silent trial evaluation of this model prospectively

Results

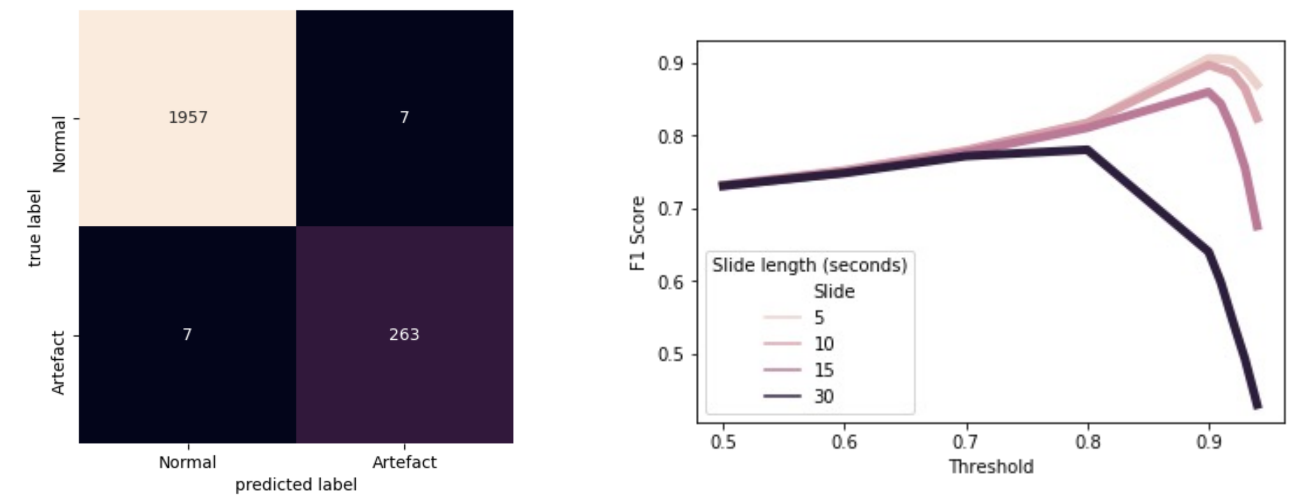

Figure 3. A) Confusion Matrix on test set B) F1 Score over one calendar year of continuous labelled waveform.

Prospective Evaluation

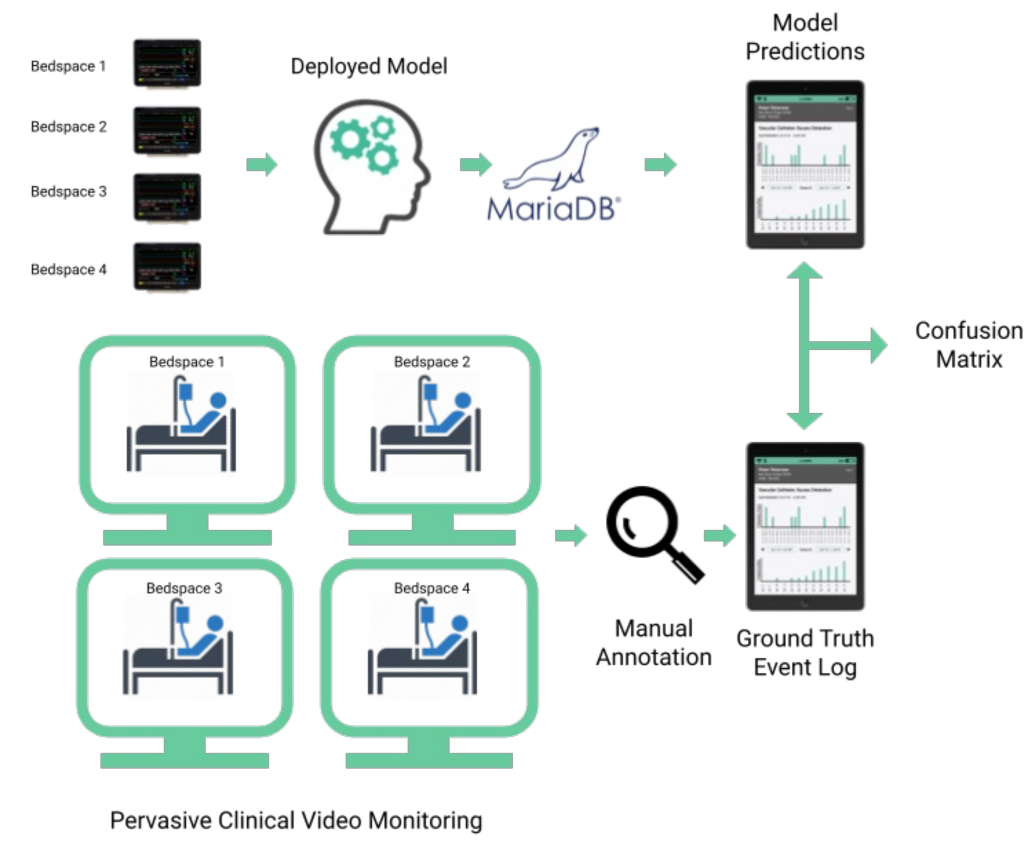

Figure 4. Proposed prospective evaluation framework.

- Model predictions will be prospectively validated with manual annotation of bedside interventions through pervasive clinical video monitoring

Applications

1. **Quality Improvement**
   i. Initiatives to reduce line access using highly accurate information about line utilization patterns
2. **Risk Assessment**
   i. Ascertaining whether changing patterns of line access can be a proxy to changing patient status
3. **Data Science**
   i. Accurately time-aligning biomarkers and medication administration
   ii. Identifying periods of time where waveform data does not reflect patient physiology

Conclusion

- Artefacts contain important clinical information and can be accurately labelled in real-time using computational tools
- These tools are free of human error, omission, and bias
- Artefact detection can help augment our clinical datasets with additional information relevant to patient care